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Development of Socio-Scientific Inquiry-Based Worksheets for Enhancing Critical Thinking on the Reproductive System Topic in Upper Secondary School

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ABSTRACT

This study responds to the lack of contextual and student-centered learning in biology, particularly in the human reproductive system, contributing to low levels of students' critical thinking skills. To address this, Socio-Scientific Inquiry-Based Learning (SSIBL)-based worksheets were developed to enhance the essential thinking skills of Grade XI senior high school students, in alignment with 21st-century education demands and the Merdeka Curriculum. The development adopted the 4-D model (Define, Design, Develop, Disseminate) and utilized validation sheets, practicality questionnaires, and critical thinking tests grounded in Facione's (1990) six indicators. The open-ended test items contextualized real-life problems and categorized them as socio-scientific issues. Validation involved media experts, subject matter experts, and SSIBL specialists; teachers and students evaluated practicality; and effectiveness was determined through pretest–posttest N-Gain analysis. Results showed the Worksheet to be highly valid (91.6%), practical (teachers: 96%, students: 92%), and effective (N-Gain = 0.84; high category). As a curriculum innovation, this SSI-based Worksheet aligns with the Merdeka Curriculum, fostering 21st-century competencies by engaging students in socio-scientific issues that cultivate understanding, critical thinking, collaboration, and technological literacy for real-world readiness.

Keywords: Worksheet, Socio-scientific inquiry-based learning, Critical thinking, Reproductive system, 4D development model

Introduction

Critical thinking is one of the essential 21st-century skills required in everyday life. This skill enables students to analyze information, identify problems, evaluate solutions, and make rational decisions (Facione, 2011; Ennis, 2011). It is regarded as a fundamental necessity in the 21st century (Siska et al., 2020; Soepriyanto, 2018) and is defined as rational, reflective, and responsible thinking (Ahmatika, 2016). Critical thinking can also be viewed as an individual's ability to translate their thought patterns in response to incoming stimuli (Ajwar et al., 2015). In the educational context, critical thinking is a core learning objective in science teaching, including biology, as it allows students to analyze biological phenomena, evaluate evidence, and comprehend complex conceptual relationships within biological systems more comprehensively (Brookhart, 2010).

According to Nainggolan et al. (2018), every educational level should actively cultivate students' critical thinking skills. Beyer (1995) defines critical thinking as assessing and evaluating ideas or arguments using explicit criteria, from the simplest to the most complex. This skill enables learners to navigate complex problems, make informed judgments, and approach issues from multiple perspectives. In science education, critical thinking empowers students to question assumptions, analyze data, and synthesize information into coherent conclusions that can be applied to real-world situations. Facione (2011) further explains that critical thinking involves deciding what to believe and do based on reasoning, gathering necessary information, and considering alternatives.

However, empirical evidence indicates that Indonesian students consistently exhibit low critical thinking skills. According to the Programme for International Student Assessment (PISA), Indonesia ranked 74th out of 79 participating countries in science literacy, highlighting a significant deficiency in analytical and evaluative skills (Intan, 2024). National studies have also revealed that students struggle to connect biological concepts, interpret data, and draw valid conclusions (Herlanti et al., 2023). This deficiency is further exacerbated by the predominance of teacher-centered instructional practices, which emphasize rote memorization more than inquiry-based learning (Saputra et al., 2019; Trisnani, 2024).

This condition is particularly evident in biology learning, where complex and abstract topics—such as the human reproductive system—are often delivered without clear contextual connections. Without meaningful integration between scientific concepts and students' lived experiences, the learning process becomes fragmented, making it difficult for learners to see the relevance of the material. Moreover, the absence of inquiry-based approaches and socio-scientific discussions limits opportunities for students to develop critical thinking skills, problem-solving abilities, and informed decision-making related to biological issues. As a result, students memorize facts without understanding their applications or significance in real life, leading to limited engagement and conceptual mastery (Wasis, 2017).

The Socio-Scientific Inquiry-Based Learning (SSIBL) approach has emerged as a promising pedagogical strategy to address these challenges. SSIBL integrates real-world, controversial, and science-related issues, encouraging students to consider ethical dimensions, multiple perspectives, and evidence-based reasoning in the learning process (Zeidler & Nichols, 2009). Numerous studies have demonstrated that SSI-based learning can enhance critical thinking, argumentation skills, and scientific literacy (Hardianti & Pamelasari, 2023; Kartika, 2024; Salsabila et al., 2023). Furthermore, this approach engages students in reflective discussions, encourages critical evaluation of scientific evidence, and facilitates formulating well-reasoned positions on complex issues (Nuangchalerm, 2010; Wahyu, 2024).

Nevertheless, SSI-based learning remains rare at the secondary school level, primarily due to the lack of instructional materials that integrate SSIBL. One essential material is the Worksheet, which is commonly used by teachers to facilitate students' cognitive development, concept discovery, and application in everyday life (Firdaus, 2018; Prastowo, 2015; Trianto,

2010). Well-designed worksheets can support both independent and collaborative problem-solving, particularly when they integrate scientific and social perspectives (Evagorou et al., 2012; Septaria et al., 2025).

Field findings reveal a gap in the development of the SSIBL-based Worksheet, particularly in biology topics such as the human reproductive system. This topic is often perceived as difficult by students due to its complex concepts, which are closely related to cell biology, making it challenging for them to fully grasp the interconnections among concepts (Ananda & Indayana, 2022; Harahap, 2024; Sridailani et al., 2018). In addition to being abstract, the reproductive system is also considered sensitive, thus requiring learning materials that are not only scientifically accurate but also socially relevant and ethically grounded. This condition calls for instructional strategies that enable students to develop deep conceptual understanding rather than merely receiving information. In line with Trianto's (2010) perspective, instruction tailored to students' characteristics and needs can serve as an effective means to overcome these obstacles.

Although the use of interactive learning media such as e-modules and e-books has become more common in recent years (Fitria et al., 2024; Putri & Suryani, 2023), the development of SSIBL-based worksheets, particularly for complex and value-laden topics such as the human reproductive system, remains limited in senior high school biology education in Indonesia. This reflects a significant gap, given the potential of the Worksheet as tangible and structured media to promote student-centered and inquiry-based learning. Therefore, this study offers a novel contribution by developing a valid, practical, and effective SSIBL-based Worksheet that not only aligns with the objectives of the Merdeka Curriculum but also directly supports the development of 21st-century competencies. This innovation is essential for improving the quality of biology teaching and empowering students to think critically and act responsibly when addressing Socio-Scientific Inquiry-Based Learning in real-life contexts.

Methods

Research Design

This study employed a Research and Development (R&D) approach by adopting the 4-D development model, which consists of four stages: (1) Define, (2) Design, (3) Develop, and (4) Disseminate (Thiagarajan, 1974). However, in this study, the dissemination stage was not carried out due to time and budget constraints.

Figure 1. 4D Model Design (Thiagarajan, 1974)

This study was conducted in Grade XI at SMA Swasta Cerdas Murni with a sample of 25 students. The research instruments included validity testing, practicality testing, and effectiveness testing. The validity test was carried out using validation sheets completed by media experts and subject matter experts to assess the feasibility and content suitability of the developed Worksheet. The practicality test was conducted by distributing questionnaires to one teacher and 25 students to obtain feedback on the ease of use and comprehensibility of the Worksheet. Meanwhile, the effectiveness test was implemented using a critical thinking skills test consisting of six essay questions developed based on Facione's (2011) critical thinking indicators, which include interpretation (understanding and explaining the meaning of information or concepts), analysis (identifying relationships between concepts or pieces of information), evaluation (assessing the credibility of sources or the strength of arguments), inference (drawing logical conclusions from given data or statements), explanation

(presenting reasons or evidence supporting a decision or conclusion) and self-regulation (the ability to control one's thinking processes to remain focused, systematic, and objective in making decisions or solving problems).

Table 1. Test Instrument Blueprint Based on Facione's (2010) Critical Thinking Indicators for the Topic of the Reproductive System and the Analysis of Early Marriage Issues

Indicator	Example Question
Interpretation	Based on what has been learned and discussed regarding the process of cell division, what is your understanding of the reproductive system and its relation to the issue of early marriage in the context of the reproductive system?
Analysis	From frequently occurring cases, many problems may arise as a result of early marriage, one of which is its impact on the reproductive system, particularly in women who marry at a young age. Explain and analyze how early marriage can affect one of the structural organs in the reproductive system, and describe what may occur.
Evaluation	Based on the discourse, phenomena, and data presented regarding early marriage, do you believe that early marriage affects the reproductive process? What measures should be taken to ensure that this social issue of early marriage is not followed by children and adolescents? However, if early marriage still occurs due to economic factors, what steps can be taken by young couples to maintain their reproductive health?
Inference	Based on the data presented above, do you think early marriage can support reproductive health or, on the contrary, cause disorders in the reproductive system, considering the young age and the physical and mental readiness that is not yet optimal? Conclude in your own words.
Explanation	What if early marriage is carried out without careful consideration of physical and mental readiness? Logically explain your reasoning or opinion, based on evidence you have encountered or read from various sources.
Self-Regulation	As the young generation, what should be done to maintain reproductive health?

Before its use, the critical thinking test instrument was validated by subject matter experts to ensure its appropriateness and quality. The validation results indicated a percentage score of 90% for the content aspect, demonstrating that the test items were relevant and aligned with the intended measurement objectives. The construction aspect obtained a score of 75%, indicating that the structure and organization of the items met the validity standards satisfactorily. The language aspect achieved a score of 80%, signifying that the wording of the items was clear and easily understood by the respondents. The overall average score reached 82%, which falls within the "highly valid" category, confirming that the instrument is suitable for use in the study.

Data Analysis Technique

This developmental research used both test and non-test instruments. Test data were obtained from students' scores on the critical thinking ability test. Non-test data were obtained from validation ratings by expert reviewers and questionnaires evaluating the responses of teachers and students.

$$\text{Percentage} = \frac{\text{Obtained Score}}{\text{Maximum Score}} \text{ x } 100\% \ \ldots \text{ (formula 1)}$$

Table 2. Worksheet Validity Criteria

Percentage	Validity Criteria	Description
0% – 44%	Not Valid	Requires total revision
45% – 64%	Less Valid	Major revision needed
65% – 84%	Valid	Minor revision
85% – 100%	Very Valid	No revision needed

(Sari, 2024)

$S = \frac{\sum \mathbf{p}}{\sum \mathbf{n}}$ … (formula 2)

Where:

S = Score per aspect

∑p = Total score per aspect from all students

∑n = Number of students

The validity analysis focuses on the Worksheet developed in this research. If the expert validation results meet the criteria for validity, then the Worksheet is considered valid.

Table 3. Worksheet Practicality Criteria

Score	Description
0% – 20%	Very Impractical
21% – 40%	Not Practical
41% – 60%	Fairly Practical
61% – 80%	Practical
81% – 100%	Very Practical

(Irawan, 2024)

N-Gain = $\frac{\textit{Score pre test} - \textit{Score post test}}{\textit{Score maximum} - \textit{Score pre test}}$ … (Formula3)

Table 4. N-Gain Classification of Worksheet Effectiveness

N-Gain Score	Classification	Description
N-Gain ≥ 0.7	High	Effective
0.3 ≤ N-Gain < 0.7	Medium	Moderately Effective
N-Gain < 0.3	Low	Not Effective

(Kurniawan, 2021)

Effectiveness analysis is based on students' success in completing learning outcomes evaluations. Pre-tests and post-tests are conducted during field trials to evaluate the effectiveness of newly developed products. Comparison of N-Gain scores was carried out to determine the effectiveness of the Worksheet in improving student learning outcomes. In addition, the pre-test and post-test results were analyzed statistically using the Wilcoxon test,

a test for normality of data distribution, to determine whether the observed differences were statistically significant.

Results and Discussion

This development research produced a Socio-Scientific Inquiry-Based Learning (SSIBL) Worksheet that is focused on developing students' critical thinking skills in learning the reproductive system material. This Worksheet is designed to encourage students to analyze contextual issues, formulate questions, evaluate arguments, and make decisions based on evidence and logical reasoning. The development process of this Worksheet followed the stages of the 4D model (Define, Design, Develop, and Disseminate). The following sections describe the findings at each stage of the development of the SSIBL Worksheet carried out in this study.

Define Phase

The Define phase began with a preliminary study at Cerdas Murni Private High School to identify relevant learning problems as the basis for media development. This phase included five main steps, namely: initial analysis to identify learning needs; learner analysis to determine students' characteristics and initial abilities; concept analysis to examine the reproductive system material following the curriculum; task analysis to map activities that promote critical thinking; and the specification of instructional objectives to be achieved. The results of this phase are presented in the following table.

Table 4. Components and Results of the Define Phase Analysis in Media Development

Component	Activity Results
Front-End Analysis	Observations and interviews revealed that students' critical thinking skills were still low, as reflected in an average pretest score of 38.84 out of a maximum score of 100. Teaching dominated by lectures, reliance on textbooks, and large class sizes was identified as a major obstacle. The teacher reported that students' learning motivation was low because the material presented was neither engaging nor contextualized. One teacher stated, "Students tend to be passive because the material is only read from the textbook, and they find it difficult to relate the lessons to real-life situations." Meanwhile, several students expressed that the learning process felt monotonous and difficult to understand, for example, "Sometimes we just memorize, but we don't understand how to apply it in the real world".
Learner Analysis	Questionnaires showed that the learning media used were less attractive and not interactive. Students wanted a Worksheet that matched their learning styles and could increase their engagement.
Concept Analysis	The human reproductive system was chosen for this study because research shows it is an important yet often poorly understood topic. For example, studies have found that many students still lack adequate knowledge of reproductive anatomy and physiology, indicating a need for better curriculum content (Albeitawi, 2024). Other research shows that reproductive health education can significantly improve both knowledge and behavior among adolescents (Kumalasari, 2020). Beyond its biological importance, this topic is connected to socio-scientific issues such as early marriage and premarital sexual activity, which have serious health, social, and ethical impacts. Using these issues in learning

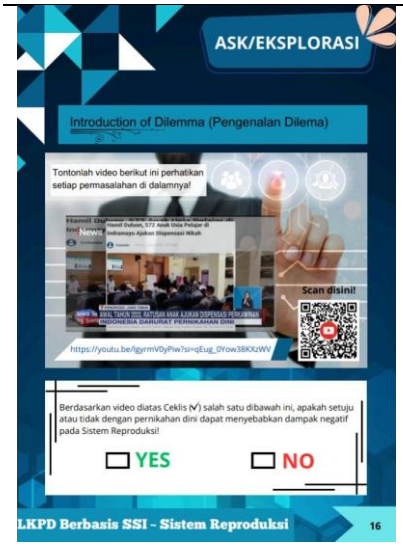
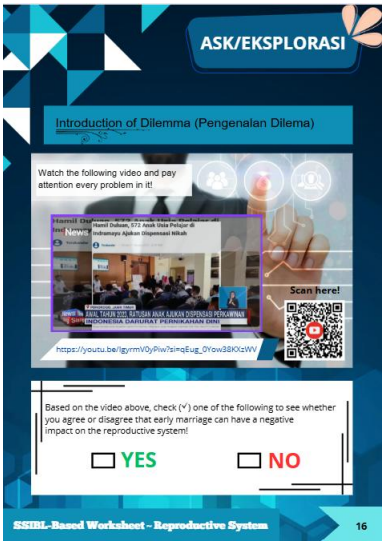
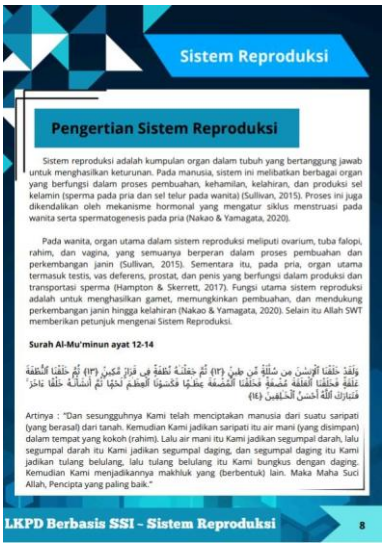
Component	Activity Results
	provides a meaningful context for applying scientific knowledge, evaluating evidence, and forming informed opinions. Therefore, it is necessary to develop learning materials that not only teach biological concepts but also connect them to real-world socio-scientific issues. This approach supports the Merdeka Curriculum, which promotes contextual, student-centered learning and higher-order thinking skills. By embedding these issues in lessons, students can practice inquiry, argumentation, and evidence-based decision-making—essential skills for the 21st century. This study aims to create and evaluate Socio-Scientific Inquiry-Based Learning (SSIBL) worksheets to improve critical thinking and raise awareness of the broader social implications of reproductive health.
Task Analysis	Learning needs to emphasize the application of concepts and critical thinking skills, such as analyzing data, linking concepts to real life, and constructing arguments based on scientific evidence.
Specifying Instructional Objectives	Learning objectives were formulated based on Permendikbudristek No. 32 Year 2024, including: (1) Identifying the structure and function of the reproductive system; (2) Explaining mitotic and meiotic cell division; (3) Applying concepts of disorders and diseases of the reproductive system in daily life; (4) Analyzing healthy lifestyle patterns to maintain reproductive health; (5) Evaluating prevention information of reproductive disorders scientifically.

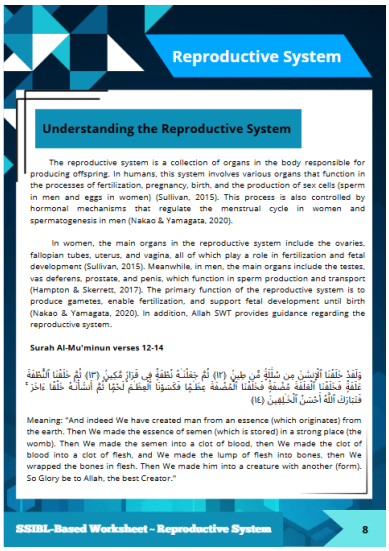
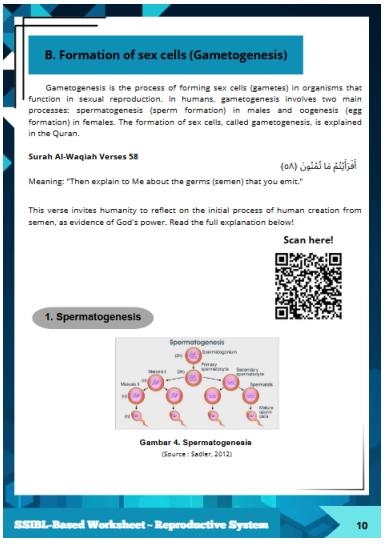
Design Phase

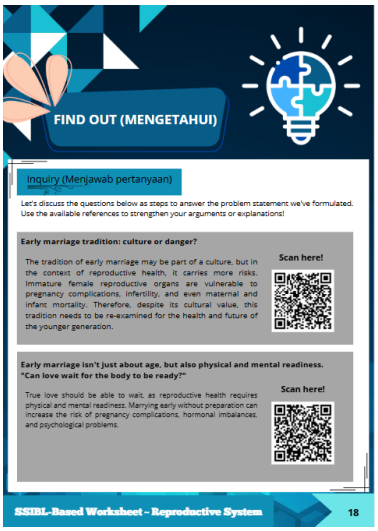
Based on the analysis findings from the Define phase, the researcher developed a Socio-Scientific Inquiry-Based Learning (SSIBL) Worksheet with an inquiry approach that was designed to improve students' critical thinking skills in understanding human reproductive system material. This Worksheet facilitates students to explore relevant contextual issues, assess various perspectives, and construct logical arguments based on scientific data and facts. In the design phase, planning included not only the content structure but also visual aspects and the coherence of thinking flow within the Worksheet. The design was carried out using the Canva application by considering color combinations that are pleasing to the eye, a systematic layout, and the presentation of information that is attractive and easy to understand.

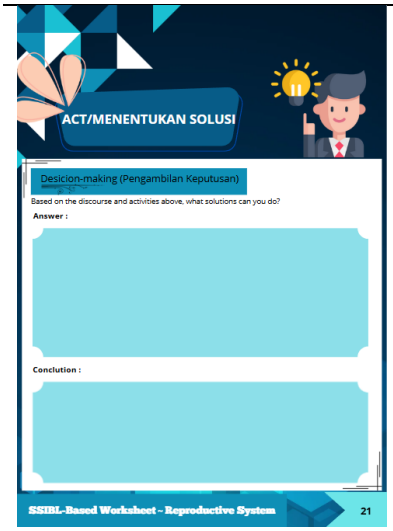
The contents of the Worksheet include: cover, foreword, user instructions, diagnostic assessment, concept map, inquiry-based learning activities (from problem orientation to evaluation), reflection, glossary, and bibliography. To ensure the quality of the Worksheet, the researcher also developed several data collection instruments, such as expert validation sheets (to assess the feasibility of content and design), practicality questionnaires for teachers and students, and pretest-posttest blueprints (to measure the effectiveness of the Worksheet in enhancing critical thinking skills). Activities in the Worksheet were designed to encourage students to analyze Socio-Scientific Inquiry related to reproductive health, formulate solutions, and evaluate arguments through group discussion, data analysis, and evidence-based decision-making.

Table 5. Worksheet Presentation, Learning Activities, and Critical Thinking Indicators

Worksheet Presentation	Learning Activities	Critical Thinking Indicators
	Students identify real issues, analyze causes and impacts, evaluate information, and formulate solutions based on data and logic. This activity develops reflective, argumentative, and responsible thinking.	Students identify real-world issues, analyze causes and effects, evaluate information, and formulate solutions based on data and logic. These activities foster reflective, argumentative, and responsible thinking (Cendana, 2023).
		
	Students analyze biological concepts from scientific and spiritual perspectives, evaluate information based on religious texts (*dalil syar'i*) and scientific evidence, and derive meaningful and ethical conclusions.	Students analyze biological concepts from both scientific and spiritual perspectives, demonstrating the ability to interpret core ideas in various contexts (interpretation), examine underlying relationships and principles (analysis), and evaluate information using religious texts and scientific evidence (evaluation). They then draw conclusions that are not only logical but also ethically responsible (inference and

Worksheet Presentation	Learning Activities	Critical Thinking Indicators
		explanation). This integrative approach fosters critical thinking by encouraging students to reflect on their reasoning processes and align them with moral and spiritual values (self-regulation) (Facione, 1990).
	Students evaluate the consistency of images with scientific concepts, link them with religious values, and draw critical and comprehensive conclusions.	Students evaluate the appropriateness of images with scientific concepts, relate them to religious values, and conclude critically and comprehensively.
		

Worksheet Presentation	Learning Activities	Critical Thinking Indicators
	Students access and analyze information logically, evaluate reproductive health issues, and draw conclusions based on evidence and ethical considerations.	Students access and analyze information logically, evaluate reproductive health issues, and draw conclusions based on evidence and ethical considerations.
		
	Students identify issues, analyze impacts, consider multiple perspectives, and formulate solutions through collaboration and logical reasoning.	Students identify issues, analyze impacts, consider multiple perspectives, and formulate solutions through collaboration and logical reasoning.

Worksheet Presentation	Learning Activities	Critical Thinking Indicators
		

Develop Phase

In this phase, the researcher prioritized quality assurance of the Worksheet content and functionality to ensure it met content feasibility standards and had high usability in the classroom learning context. Referring to Jayanti & Pertiwi (2023), the validation process was carried out before implementation to ensure the product met feasibility standards from various aspects. Validation involved three experts who assessed several key dimensions: appearance design (Media), content alignment with the reproductive system material in the Merdeka Curriculum (Content), and integration of science literacy and Socio-Scientific Inquiry-Based Learning approach (SSIBL). These assessments formed the basis for product improvements before proceeding to practicality and effectiveness testing.

The validation results provided by the three experts are presented in detail in the following table, which serves as the basis for refining the Worksheet before implementation.

Table 6. Validation Results of the Worksheet by Media, Content, and Socio-Scientific Inquiry-Based Learning Experts

Expert	Aspect Assessed	Item Statement	Score	Max Score	Percentage	Criteria
Media	Graphic Design of Media	8	31	32	97%	**Very Valid**
	Content Presentation	8	29	32	91%	
	Average (%)				**94%**	
Content	Content Feasibility	7	25	28	89%	**Very Valid**
	Language	8	27	32	84%	
	Material Presentation	8	29	32	91%	
	Average (%)				**88%**	
SSI (n=2)	Content Feasibility	3	11.5	12	96%	**Very Valid**
	Construction Feasibility	3	11	12	92%	
	Language Feasibility	3	11	12	92%	
	Format & Appearance Suitability	2	7	8	88%	
	Average (%)				**92%**	

Based on Table 4, the experts' results of the Worksheet validation indicate that the product was rated as very valid and feasible to be used in the learning process after revisions were made following the validators' suggestions. Validation was conducted on media,

content, and the Socio-Scientific Inquiry-Based Learning (SSIBL) approach, which are the main pillars in developing this Worksheet. From the media aspect, the assessment included graphic design and content presentation. The highest score was obtained in the graphic design indicator (97%), while content presentation reached 91%. The overall average score of the media expert was 94%, which falls into the **very valid** category. This indicates that the Worksheet was designed with an attractive, proportionate visual appearance appropriate for student needs. This finding aligns with Murdianti (2024), who states that visual design quality plays a vital role in increasing students' interest and engagement during learning processes in both digital and print-based media.

From the content side, three aspects were assessed: content feasibility, language, and material presentation. They obtained scores of 89%, 84%, and 91%, respectively, with an average score of 88%, which falls into the **valid** category. This means that the content presented in the Worksheet aligns with the Merdeka Curriculum learning outcomes, uses communicative language, and contains a systematic presentation structure. This result is reinforced by Lestari (2024), who states that appropriate language use and structured material presentation can enhance students' conceptual understanding, especially on complex topics like the reproductive system.

Meanwhile, the Socio-Scientific Inquiry-Based Learning (SSIBL) aspect was validated by two experts who evaluated the dimensions of content feasibility, construction, language, and format/appearance suitability. The four dimensions received scores of 96%, 92%, 92%, and 88%, respectively, with an overall average of 92%, which belongs to the **very valid** category. This indicates that the Worksheet has integrated the SSI approach conceptually and technically. This finding is further supported by Syahla (2024), who affirms that using the Socio-Scientific Inquiry approach can build students' critical thinking abilities and social awareness through exposure.

Overall, the expert validation resulted in average scores above 85%, indicating that the worksheet is in the valid to very valid category across all assessed aspects. This validity provides a strong foundation to proceed to the practicality and effectiveness testing stages while also confirming that the developed worksheet has met the pedagogical, visual, and scientific substance standards required for socio-scientific inquiry-based learning.

Next, a practicality test was conducted by distributing response questionnaires to teachers and students as direct users. The results of this practicality test are presented in the following table:

Table 7. Practicality Test Results by Students and Teachers

Respondent	Item Statements	Obtained Score	Max Score	Percentage	Criteria
Students (n=25)	23	84.7	92	92%	Very Practical
Teachers	12	46	48	96%	Very Practical

Based on the data in Table 5, responses from students and teachers indicate that the developed media falls into the very practical category. Twenty-five students scored 92%, reflecting a positive perception of appearance, activity flow, and ease of understanding the Worksheet content. The material packaged through the Socio-Scientific Inquiry approach was perceived to encourage active engagement and stimulate critical thinking, especially when learners were asked to analyze real cases, consider various perspectives, and formulate solutions. This finding aligns with Pradana (2022), who asserts that contextually social-scientific-based media effectively enhance reasoning ability and the capacity to evaluate information logically.

Meanwhile, teachers scored 96%, indicating that the Worksheet supports flexible instruction and aligns with current curriculum approaches. Clear instructions, structured activities, and integrating scientific values with life contexts helped teachers manage the class. This is supported by Fitria & Mulyani (2021), who indicate that instructional tools presenting current issues enrich learning experiences and facilitate educators in building reflective classroom discussions. Overall, this test shows that the developed Worksheet is technically practical and pedagogically relevant, as it nurtures critical thinking through exploration of real and scientific-social problems. This practicality becomes a strong basis to proceed to the effectiveness test to assess its impact on student learning outcomes.

Table 8. Effectiveness Test Results of the Developed Worksheet Based on N-Gain Analysis

Evaluation	Average Score	Max Score	N-Gain Score	Criteria
Pretest (n=25)	38.84	100	0.84	High / Effective
Posttest (n=25)	90.12	100		

The effectiveness assessment was conducted to measure how much the SSIBL-based Worksheet could enhance students' critical thinking skills after the learning process. Based on the pretest and posttest analysis using the N-Gain formula, the average pretest score was 38.84, while the average posttest score reached 90.12. The calculated N-Gain value was 0.84, which falls into the high category, indicating that the developed Worksheet effectively improved students' learning outcomes. These data were also visualized based on students' scores for each test item indicator.

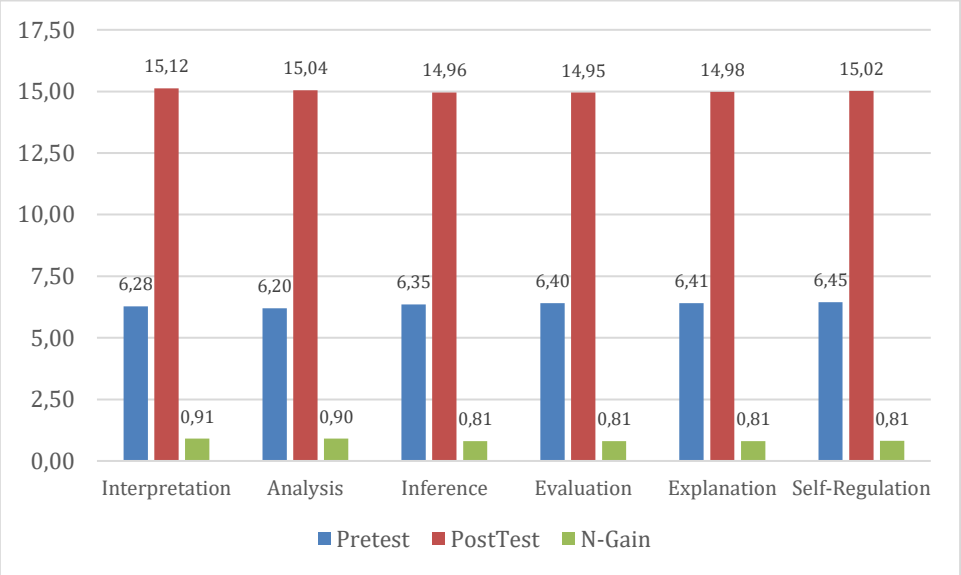


Figure 2. Distribution of students' score improvement for each critical thinking skill indicator

Figure 2 shows that all indicators of critical thinking skills experienced a significant increase after implementing the SSIBL-based Worksheet. In the pretest phase, the average score for each indicator ranged from 6.20 to 6.45, whereas in the posttest phase, it sharply increased to approximately 14.95–15.12. The greatest improvement was observed in the Interpretation indicator (N-Gain = 0.91), followed by Analysis (N-Gain = 0.90). In contrast, the Inference, Evaluation, Explanation, and Self-Regulation indicators each recorded an N-Gain value of 0.81. All N-Gain values fall within the high category, indicating that the Worksheet was effective overall and could positively impact all aspects of students' critical thinking skills.

To strengthen these findings, a Wilcoxon test was conducted using SPSS software. The selection of the Wilcoxon test was based on the results of the normality test of the posttest–

pretest score differences conducted earlier. The normality test using the Kolmogorov–Smirnov and Shapiro–Wilk methods showed significance (Sig.) values of 0.000 and 0.001, respectively, with a sample size of 25, since the Sig. Values for both tests were below 0.05 ($p < 0.05$), and the null hypothesis stating that the data were normally distributed was rejected. Therefore, as a non-parametric method, the Wilcoxon test was chosen to examine the significant differences between the pretest and posttest scores.

Table 9. Wilcoxon Signed Ranks Test

	Posttest - Pretest
Z	-4.432[b]
Asymp. Sig. (2-tailed)	.000

Based on the data in Table 9, the Wilcoxon Signed Ranks Test showed a Z value of -4.432 with a significance level (Asymp. Sig. 2-tailed) of 0.000, far below the α threshold of 0.05. This indicates a significant difference between the pretest and posttest scores after using the SSIBL-based Worksheet. These findings reinforce the N-Gain analysis result of 0.84 (high category), demonstrating a substantial improvement in students' critical thinking skills. Therefore, both the N-Gain test and the Wilcoxon test consistently confirm that implementing the SSIBL-based Worksheet effectively enhanced learning outcomes, as the observed changes were not coincidental but the result of a systematically designed instructional intervention.

This improvement reflects a transformation in students' thinking abilities, particularly in analysis, information synthesis, and argument evaluation related to Socio-Scientific Inquiry. It demonstrates that the SSIBL approach successfully created a learning environment that delivered content and encouraged students to actively engage in reflective thinking and decision-making based on scientific and social values. These findings align with the results of Zubaidah et al. (2016), which revealed that implementing socio-scientific inquiry-based learning can promote students' critical thinking, consideration of multiple perspectives, and responsible decision-making.

Applying this approach is highly appropriate in the reproductive system, which is rich in values, ethics, and real-life relevance. Furthermore, the findings of Syafitri (2023) support this result, showing that worksheets developed using an inquiry model based on Socio-Scientific Inquiry-Based Learning can significantly enhance students' conceptual understanding and argumentative skills. This is attributed to students' engagement in solving real-world problems that require data evaluation, causal reasoning, and decision-making grounded in scientific principles. With a high N-Gain score, the developed Worksheet functions as a practical learning medium and an effective tool for improving critical thinking skills. This success reinforces the urgency of integrating the SSI approach into biology education, particularly for topics closely linked to social life, values, and ethics, such as the reproductive system.

The results of this study demonstrate that the developed SSIBL-based inquiry Worksheet effectively facilitates students in analyzing contextual issues, posing critical questions, evaluating arguments, and making evidence-based decisions. These findings align with Firdaus et al. (2018), who reported that SSI-based learning effectively enhances critical thinking skills by presenting problems closely related to students' real-life experiences. The observed improvement in analytical skills and logical reasoning is also consistent with Sadler and Zeidler's (2005) study, which found that integrating Socio-Scientific Inquiry-Based Learning into learning encourages students to connect scientific concepts with social contexts, strengthening argumentation skills. These findings reinforce the notion that employing inquiry approaches in the Worksheet, as recommended by Azzahra (2024), not only guides students through the concept discovery process but also cultivates a critical scientific mindset.

Thus, this study supports previous research outcomes and provides a practical contribution by designing a systematic and contextual Worksheet for the reproductive system topic, which remains rarely developed with an in-depth integration of SSIBL.

Conclusion

Based on the research findings, developing a Worksheet based on Inquiry Socio-Scientific for the reproductive system in senior high schools demonstrates significant potential in enhancing students' critical thinking skills. This improvement is evident from the differences between pretest and posttest results, supported by a high-category N-Gain score, as well as positive responses from teachers and students who assessed the Worksheet as practical, engaging, and relevant to the needs of 21st-century learning. The SSIBL-based Worksheet effectively facilitates students' active engagement in solving contextual problems, linking scientific concepts with social issues, and systematically developing higher-order thinking skills. The potential for implementing this Worksheet in the future is considerable, particularly in learning contexts aligned with the Merdeka Curriculum, which emphasizes independence, collaboration, and developing critical thinking skills.

Nevertheless, this study represents a preliminary investigation with limitations, such as the small implementation duration of the trial conducted in only one school. Further research is needed to examine the effectiveness of this Worksheet on a larger scale, across various educational levels and learning contexts. Future development may also include adjusting the content to accommodate diverse student learning styles, strengthening collaborative aspects, and integrating technology-based formative assessments. Teachers and curriculum developers should begin exploring and systematically utilizing the SSIBL-based Worksheet, combining it with active learning strategies, and ensuring its alignment with the intended learning objectives.

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